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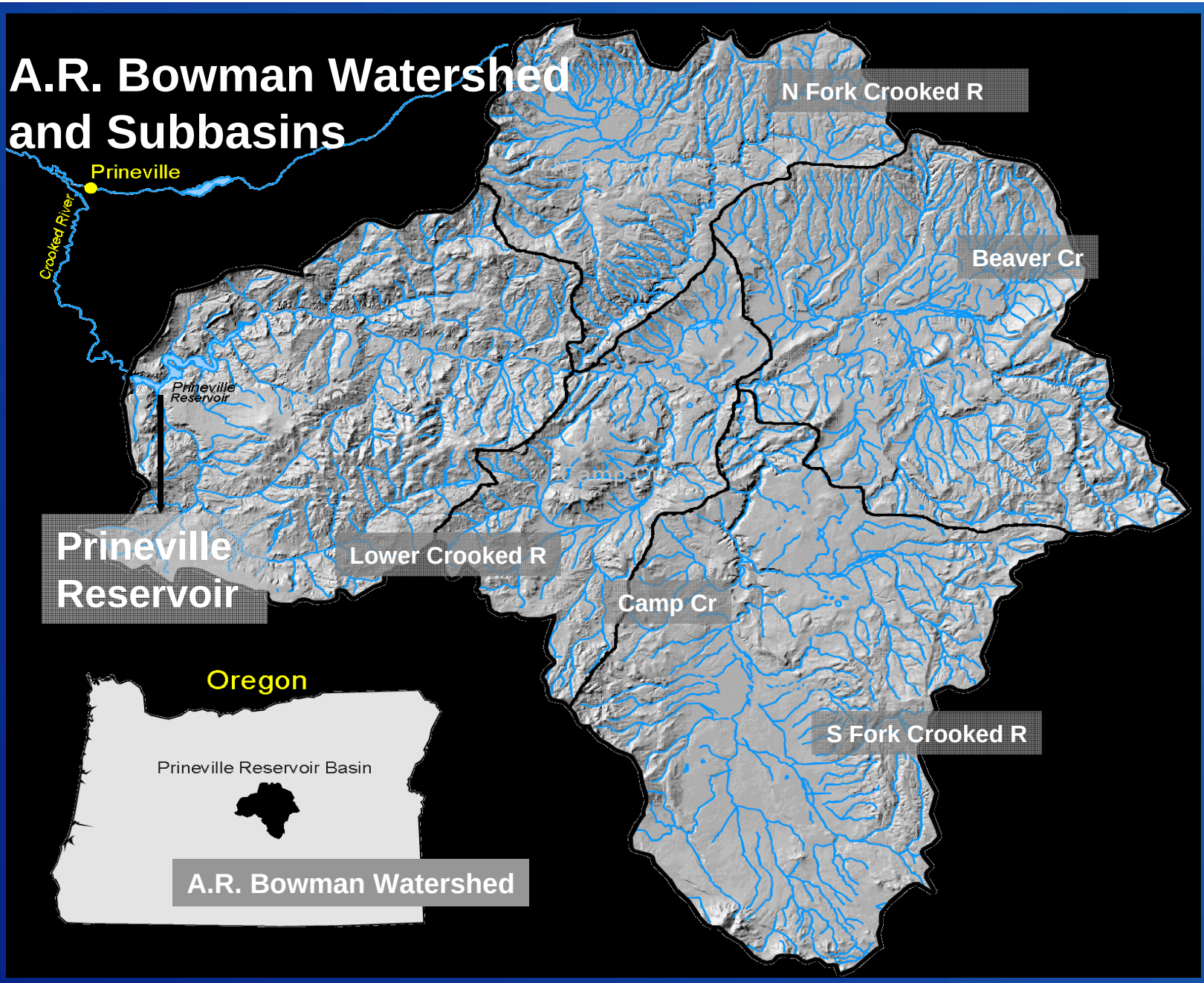
Managing Water in the West

Arthur R. Bowman Dam

Hydrologic Loadings

U.S. Department of the Interior
Bureau of Reclamation



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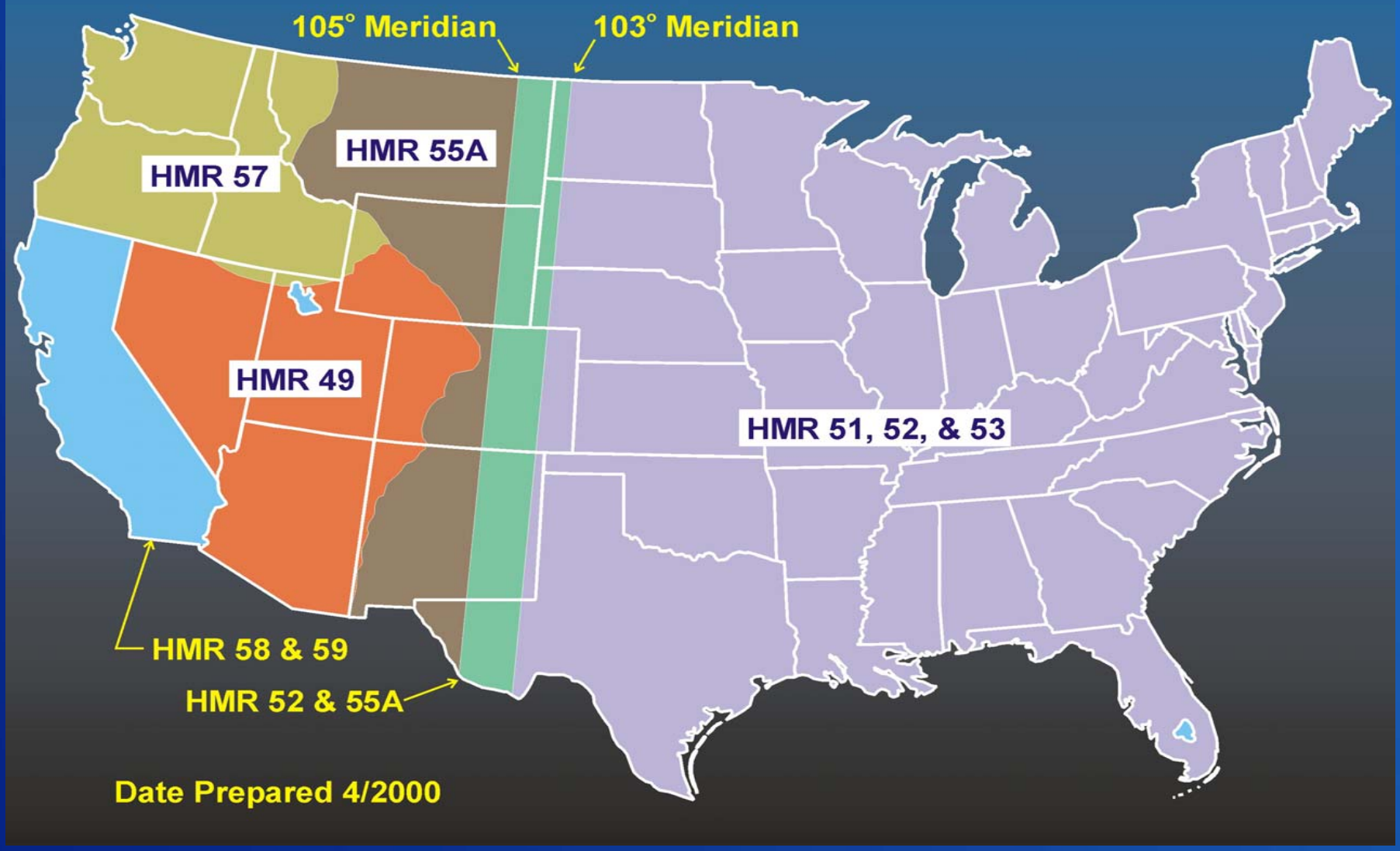
History of Hydrologic Loadings for A.R. Bowman Dam

- **Deterministic**
  - Probable Maximum Flood (PMF)
- **Risk Based (Probabilistic)**
  - Regional hydrologic data
  - Paleoflood data
  - Stochastic Flood Modeling

Deterministic -- PMF Components

- **Rainfall: Computed PMP**
  - **HMRs**
- **Rainfall Runoff Model**
  - **Infiltration (loss) rates**
  - **Unit hydrograph**
  - **Lag times**

Regions Covered by Generalized PMP Studies



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A.R. Bowman Dam – 1984 PMF

- **PMF**
  - **HMR 43 (72-hr storm)**
  - **Peak 268,000 cfs**
  - **Volume 1,034,000 ac-ft (15-day)**
  - **Overtops by 21 feet**
- **1992**
  - **Modification Report submitted to OMB**
  - **Reinforced Concrete Overtopping Protection**

A.R. Bowman Dam – 1994 PMF

- PMF
  - HMR 57
  - Peak 255,000 cfs
  - Volume 770,000 ac-ft (15-day)
  - Overtops by 18.6 feet

Road to Risk Based Evaluation

1997Mod Report withdrawn from OMB

- **Ochoco Dam**
- **Repayment Issues**
- **Risk based analyses began**

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Risk Analysis

- Quantifying/qualifying the risks posed by a dam
  - How could failure occur?
  - How likely is it?
  - What would happen if it did?
  - What is known/unknown
- Considers consequences
- Ranking dams by risk
- Examines risk reduction

Failure Modes

- **Static loads**
  - **Seepage/piping, slope stability, foundation stability, operational problems**
- **Floods**
  - **Overtopping, spillway failure, increased chance of static failure**
- **Earthquakes**
  - **Foundation liquefaction, deformation, cracking, increased chance of static failure**

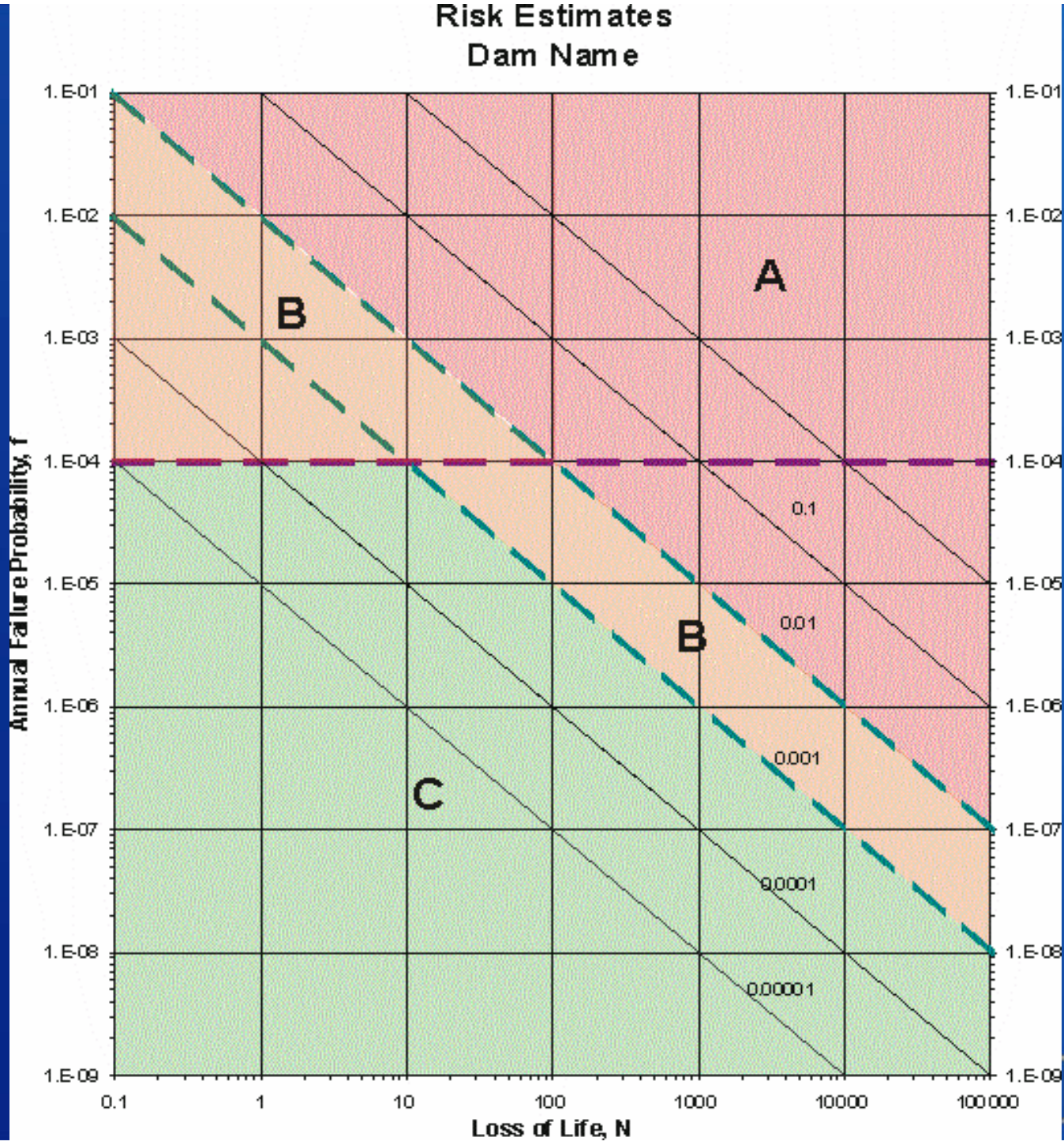
Risk Identification

- Facility Reviews
  - Annual (Checkup)
  - Periodic (O&M focus)
  - Comprehensive (Complete workup)
- Performance Monitoring
  - Visual monitoring
  - Instrumentation readings
- Reports of Unusual Conditions

Risk

- P (failure) = P (load) x P (response)
  = Annual probability of
  structural failure

- Risk = P (load) x P (response) x loss of life
  = Annual probability of loss of life


Risk Estimates
Dam Name
Annual Failure Probability, f
Loss of Life, N
1.E-01
1.E-02
1.E-03
1.E-04
1.E-05
1.E-06
1.E-07
1.E-08
1.E-09
0.1
1
10
100
1000
10000
100000
A
B
B
C
0.1
0.01
0.001
0.0001
0.00001

Results and Decision Making

- **“A’s” needs action immediately – within 90 days**
- **“B’s” cover a wide variety of actions that may be appropriate. Can be scheduled according to other priorities and funding availability. Risk reduction must be accomplished within 7 years.**
- **“C’s” The need for actions to reduce risk or conduct studies diminishes. A reasonable and prudent category.**

Examples of Risk Reduction Actions

- **Short-term actions**
  - **Investigation of uncertainties**
  - **Reservoir restrictions**
  - **Increased monitoring**
  - **Operational changes**
  - **Upgraded EAP**

Examples of Risk Reduction Actions

- **Long-term actions**
  - **Load definition**
  - **Data collection**
  - **Structural modification**
  - **Long term reservoir restriction**

Benefits of Risk Assessment

- Assess condition of Reclamation structures over a full range of loading conditions
- Improved consistency in decisions
- Better focus in SOD recommendations
- Better evaluation of proposed modifications and their associated risk reduction
- Better definition of objectives in scoping out work products

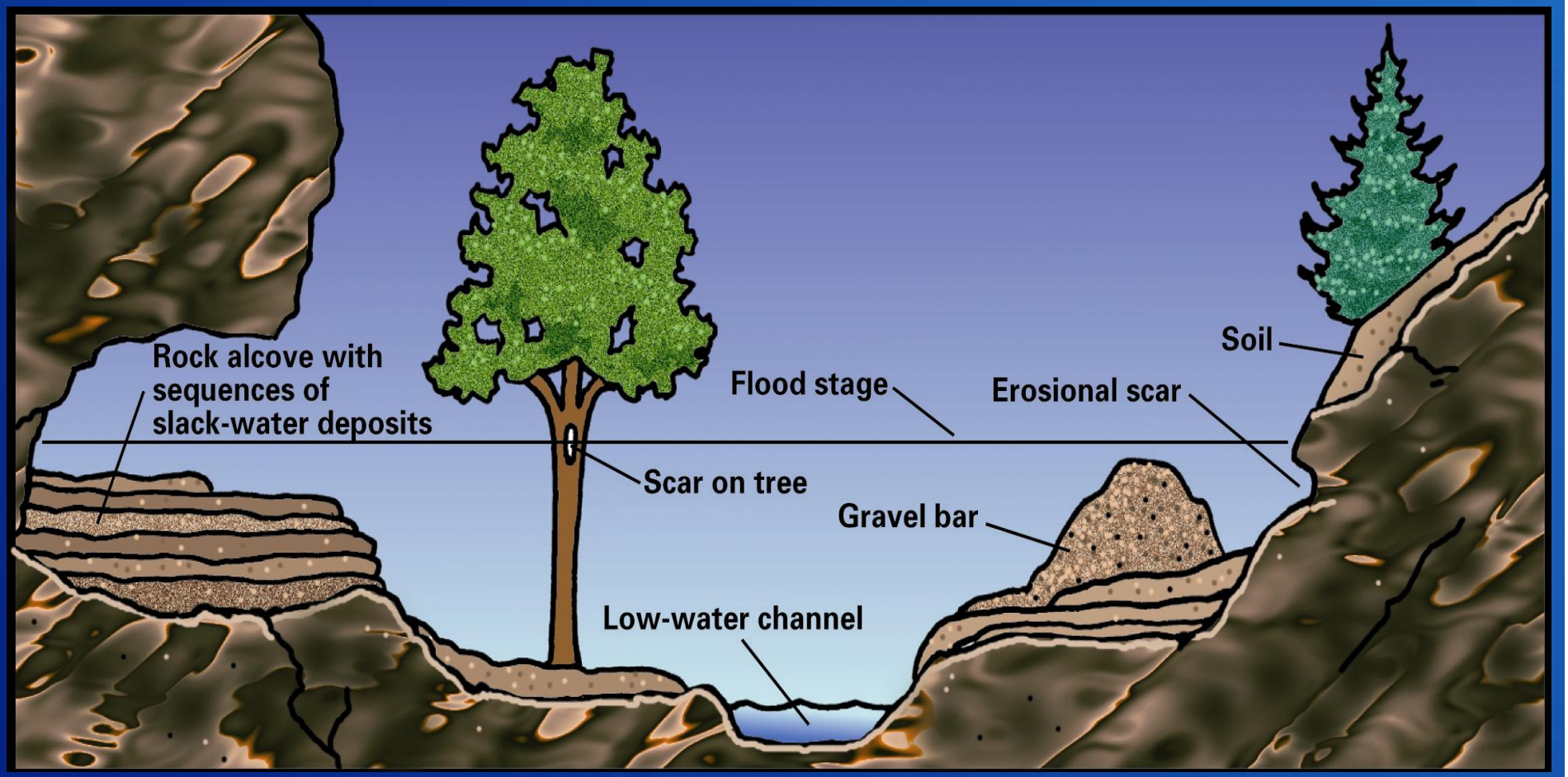
Benefits (con't)

- Complies with Federal Guidelines for Dam Safety
- More complete thought processes. Assess condition of Reclamation structures over a full range of loading conditions (extreme and lesser conditions)
- Aid in making decisions to protect public from consequences of dam failure
- Assist in prioritizing the allocation of resources
- Support justifications for risk reduction action
- Credibility in USBR and OMB
- Allows for more modifications to be done with the limited resources (money) allocated

A.R. Bowman Hydrologic Risk Evaluation

- Two Flood Hazard Approaches
  - Paleoflood Study
  - Stochastic Modeling
- Both Approaches Indicate the Magnitude of the 1/10,000 flood < 25 % of the PMF
- Needed an order of magnitude greater protection due to the magnitude of downstream impacts

Paleostage Indicators



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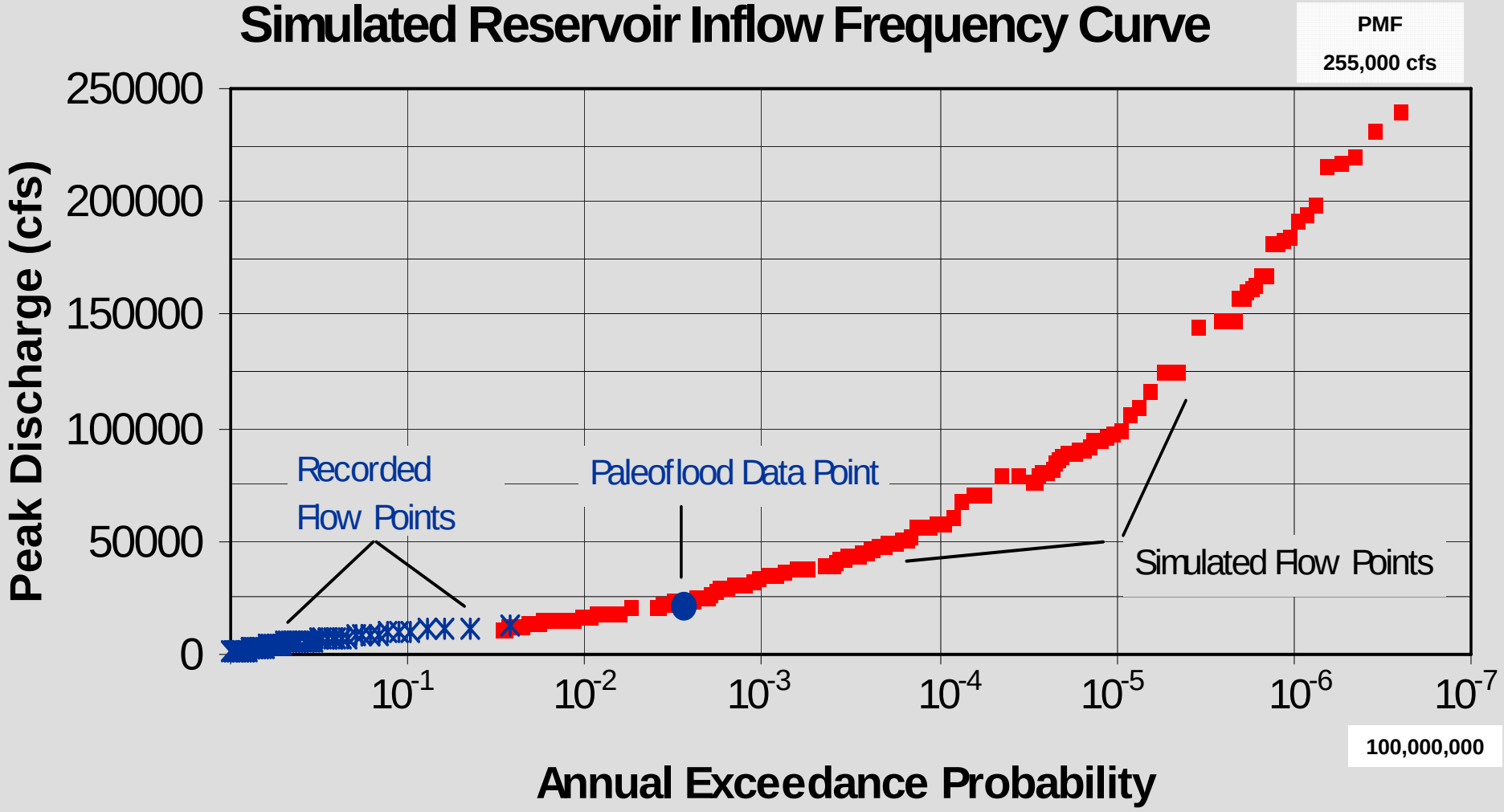
AR Bowman Dam

Simulated Reservoir Inflow Frequency Curve



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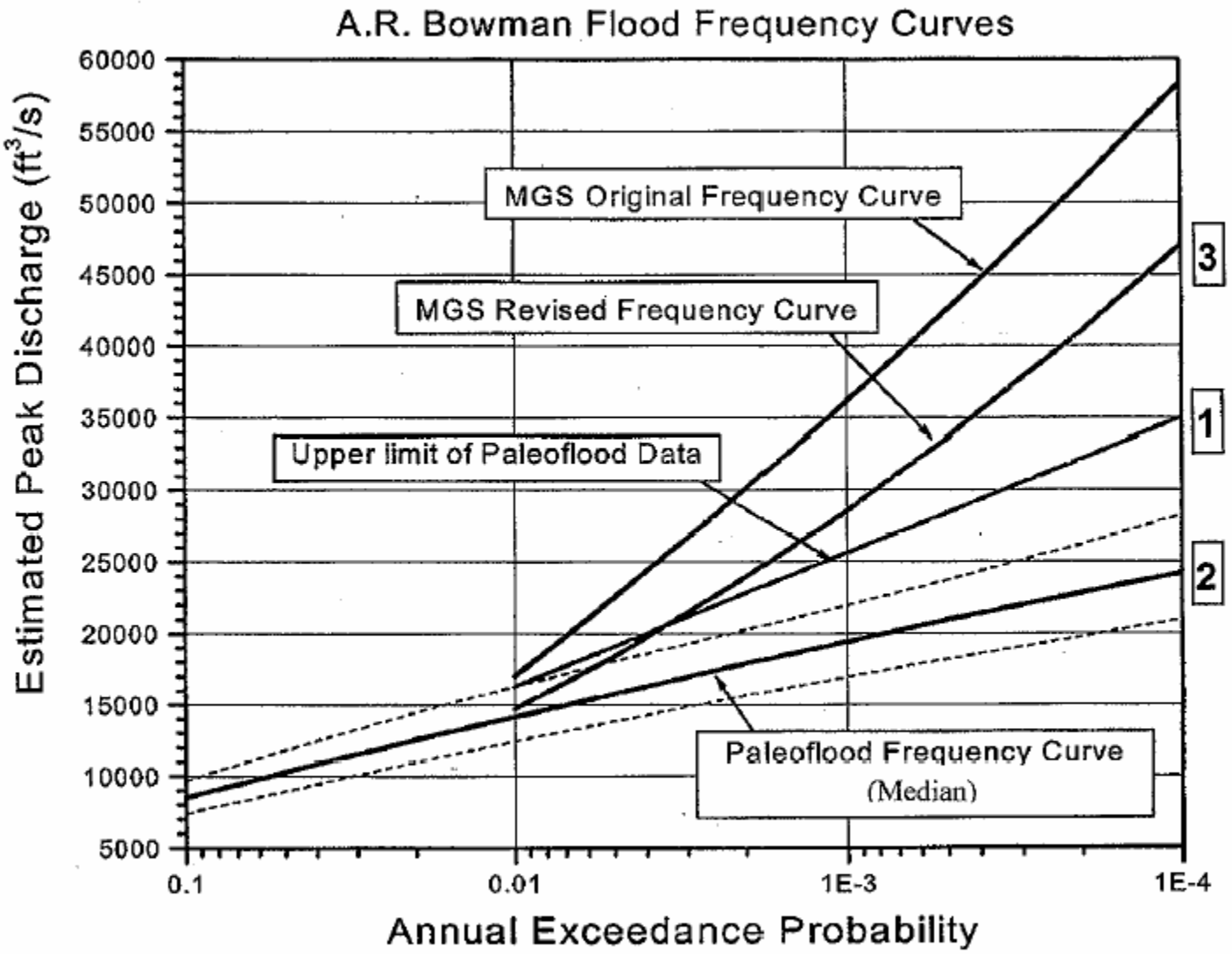
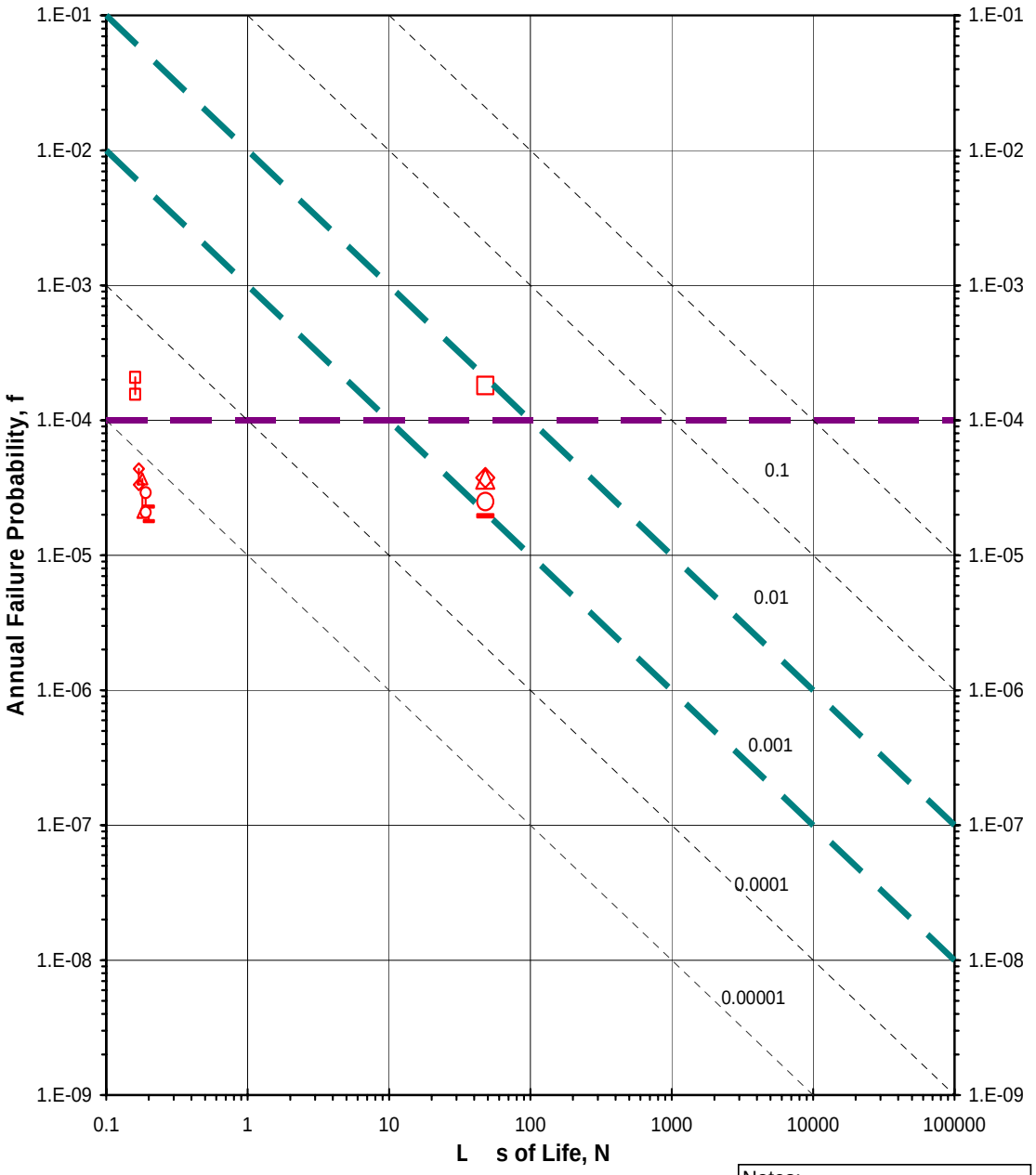


Figure A-1: Probability Curve from 2002 CFR Study (USBR 2002)

Risk Estimates
AR Bowman Dam



Hydrologic-Existing Dam

Notes:

Comparison

	Peak	Volume
PMF (1994)	255,000 cfs	770,000 ac-ft
1,000 year	24,800 cfs	216,100 ac-ft
10,000 year	37,700 cfs	329,400 ac-ft

Total discharge < 12,000 cfs @ max water surface

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Decision Making

- Other Major Factors In Final Decisions
- Legal
- Overall Technical Case
- Political
  - Operational
  - Public Involvement
- Environmental
- International

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High Risk Dams

- Use redundant measures
- Design for very low probability loading conditions
- Use best available technology
- Strive for lowest level of risk that can reasonably be achievable
- Consider how we would construct the dam today

Questions?

Karen Weghorst, PE
Program Manager, Dam Safety Office

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- First Level – 24 Point, Arial Bold
  - Second level – 20 Point, Arial Bold
    - Third level – 18 Point, Arial Bold
      - Fourth level – 16 Point, Arial Bold
        - » Fifth level – 14 Point, Arial Bold
- All Left Justified, No Centering

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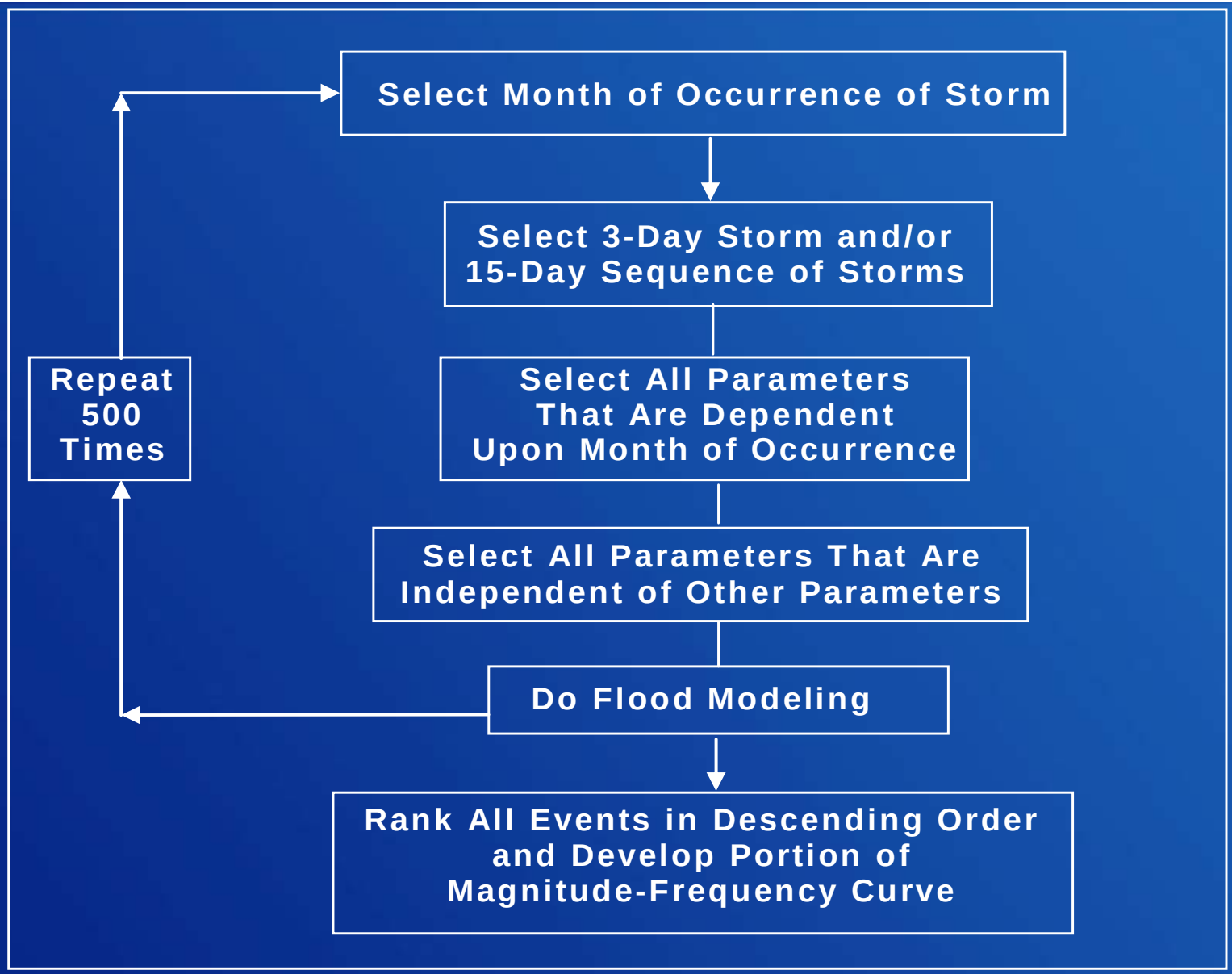
Stochastic Modeling Elements

- Hydrometeorological Parameters Treated as Variables
- Utilized 3-Day Storms and 15-Day Sequence of Storms
- Runoff Computed using Distributed Approach
- Perform 2500 Simulations to Examine Combinations Conducive to Large Floods

Probabilistic Events

- **Flood Frequency Analysis**
  - **Gage data**
  - **Log Pearson Type III frequency analysis**
  - **Bulletin 17B.**

- **Paleoflood Analysis**
  - Past or ancient flood event which occurred prior to the time of human observation or direct measurement by modern hydrological procedures.



Stochastic Simulation Flow Chart

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Evaluation of risk results

- **Decisions documented by decision makers**
- **Decisions need to be prioritized according to limited resources (time, funding, staffing)**
- **Decisions based on risk estimates and factors influencing these estimates**
- **Decisions based in incomplete/imperfect data – need to determine benefit gained by obtaining more data**
- **Risk reduction actions should reduce overall risks as low as can reasonably be achieved**
- **Credible evidence of developing failure mode**